POSTRUM: DEVELOPING GOOD POSTURE IN TRUMPET PLAYERS THROUGH DIRECTIONAL HAPTIC FEEDBACK

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Abstract: **The literature of brass pedagogy has identified the typical posture problems found in trumpet players and arrived at a consensus regarding optimal body alignment. The suggestion is that poor posture may not only hinder performance but also lead to long-term injuries. This is supported by a growing body of evidence from fields as diverse as biomechanics and pervasive healthcare. After a review of the literature, we focus on the design process used to develop Postrum; a wearable system for trumpet players that uses real-time haptic feedback to encourage better posture. In response to the multifaceted nature of the activity, the design process combines two aspects from different fields: the 'sketching in hardware' approach developed by Moussette and Dore in the context of Interaction Design (IxD), and sensing technologies from the New Interfaces for Musical Expression (NIME) field. We follow this with a brief overview of the Postrum system. This includes a 3D camera, custom software that compares the posture of the player to an idealized model, and two vibrotactile arrays mounted on the torso. Three different types of problem can be detected, their categories based on the literature. If player posture deviates from the ideal, haptic feedback is applied. Directional pulses used to indicate the corrective action needed. Finally, we offer some remarks about our experiences in relation to player engagement and performance, discuss emerging design issues, and outline implications for what Hochenbaum and Kapur term the 'practice room of the future.'**

1. INTRODUCTION

This paper explores a new posture aid for trumpet players known as *Postrum*. Our approach is informed by three bodies of theory: the literature of trumpet pedagogy from the 19th century to the present, discussion of the role and importance of haptic sensation in music, and notions of sketching and prototyping originally developed in the context of Interaction Design (IxD).

1.1. Trumpet Pedagogy

Trumpet pedagogy relates to the teaching and study of techniques for all levels of trumpet players, with broad the aim of developing or improving the abilities of the pupil. Exemplified by the maxim "Don't worry about the function, you worry about the sound" [1], trumpet pedagogy has historically focused primarily on musical output (i.e. sound) rather than the body of the player. Indeed, many tutorial materials provide numerous exercises to be performed, but little guidance on the technical and physical aspects of their mastery [2][3][4]. However, if the ability of the body to find appropriate techniques is presumed, Whitener [5] notes that "In the early stages of playing, the importance of the playing position is not always recognized" and incipient players may unwittingly adopt postures that inhibit proper respiratory function. He also points out the tendency of young players to point the trumpet downwards and recede the jaw in a manner that would adversely affect embouchure and tone. Jacobs [1] has also noted that poor posture was the most common fault among brass players and referred to a position that he termed 'standing while sitting' that would provide the best position for the lungs to operate and to support the tone oft he instrument. While the approach to teaching some aspects of playing technique remains contested, there is broad agreement about the importance of developing a posture that does not impede airflow [6][7].

The adoption of a clearly defined postural norm is supported by physiological research by Baadjou *et al.* [8] who identify an association between energy expenditure and body posture while playing brass and woodwind instruments. Their findings can be related to earlier work in non-musical contexts that considered the effect of posture on vital capacity in young adults [9][10]. For Dornbusch [11] however, the relationship between posture and sound output is more complex. He claims that the posture of the head and body impacts the position of the tongue, thus also affecting the embouchure, the articulation of staccato sounds, the quality of legato phrases, and (more tentatively) tuning stability.

Furthermore, there is growing evidence that poor posture may be detrimental to health as well as musically inexpedient. For example, a survey of 243 musicians found that 86% had suffered from regional pain in the past 12 months [12]. The respondents reported problems mainly in the neck, shoulders and lower back. Meanwhile van der Linden *et al.* [13] highlight the appearance of several clinics that specialize in the treatment of musicians. While Leaver *et al.* [12] suggest that brass players appear only half as likely to be affected by injury as those playing strings, there are still substantial numbers affected. The existence of these problems in trumpet players is supported by mentions of back, shoulder and neck pain from Campos [6], back pain from Varney [14], and muscular weakness and loss of stamina from Dornbusch [11].

If it is therefore eminently desirable to foster better posture in trumpet players, it is first necessary to identify the main issues and areas for improvement. Drawing on the literature of brass pedagogy identified above and the authors' combined six decades of experience in the field, three distinct types of posture issue can be delineated (see Figure 1).

Figure 1: Optimal posture (far left) compared to three common types of posture problems.

Within Figure 1 above, (from left to right) the first image demonstrates optimal posture allowing the lungs and ribcage freedom to operate. The second image shows the head rotated forward, thereby restricting the flow of air out from the neck and back of throat. The third image shows both the head rotated forward and the sternum collapsed, inhibiting respiration. Finally, the fourth image shows excessive sideways twisting of the body.

Figure 2: Sitting as standing posture.

In some contexts trumpet players must adopt a seated position. Perhaps the most notable examples are orchestral non-soloists.

However, the posture issues experienced are closely related [1] and pragmatically very similar to those that occur while standing (Figure 2).

1.2. Haptic Sensation

The role of haptic sensation in musical performance and its importance for instrumentalists has been extensively discussed. Marshall [15] notes that in order to produce sound, acoustic instruments require the performance interface to physically act upon (i.e. activate) the sound generation mechanism. This requirement imposes significant constraints on acoustic instrument design, but at the same time provides the performer with rich haptic feedback. For Rebelo [16], this haptic sensation is vitally important. He argues that it not only helps performers to understand the moment-to-moment response of the instrument to their input, but is also crucial for the development of longer-term performer-instrument intimacy.

1.3. Sketching and Prototyping

If the design of acoustic instruments is constrained by the need to physically couple the performance interface to the sound generation mechanism, these restrictions are largely absent in digital musical instruments (DMIs). Indeed, the designers of DMIs are afforded unprecedented freedom. Sensor technologies enable almost any physical stimuli can be used as input. Similarly, digital sound generation techniques are so numerous that essentially any imaginable sound can be created. Moreover, these two aspects are not innately co-dependent. Thus, they may be chosen independently, and the relationship between them specified by the designer. If these freedoms promise instruments and interfaces built around the human body rather than acoustical power, the exploitation of these freedoms requires flexible and exploratory development processes. At the same time, DIY and hardware hacker-orientated technologies such as the Arduino and Raspberry Pi have made the creation of functional interactive prototypes quicker and easier than ever. Holmquist [17] has discussed these rapid, iterative and often informal development processes in terms of ‘sketching in hardware.’ While it is not so important in the case of this project, Moussette and Dore [18] are keen to differentiate between sketches and prototypes. They note that sketches typically relate to the development of creative ideas, while prototypes are usually part of the preparation for production. More importantly, by sketching in hardware, designs become tangible early in the development cycle and are therefore more readily tested in near-real world conditions [19]. By testing (i.e. trying out) new designs as early as possible in their development, problems can be identified before they become entrenched, and user reactions can feed into the next design iteration [19].

2. RELATED WORK

There is a significant amount of previous research related to the posture of musicians, and numerous developments that aim to improve musicians’ posture. The latter range from off the shelf solutions to academic research projects and custom systems for individual users. While the trumpet has received relatively limited attention compared to other instrumental domains, at least two posture aids have been produced commercially. Developed by the jazz trumpeter Matt Shulman, the *Shulman System for Brass* rests on the sternum and holds the trumpet in an optimal position in front of the player. Campos [20] states that once properly adjusted, the Shulman System encourages good posture and prevents the wearer from slipping back into undesirable habits. Shulman himself [21] considers his invention liberating in that it enables a “focus on the beauty and power of the music as opposed to the physical mechanics of the performance.”

Another passive posture aid for trumpet players is the *ERGObrass*. The *ERGObone*, as it was initially called, was originally developed for the trombone as a response to the occupational pain and discomfort incurred by its designer:

> I finally realized that it was completely useless to wonder how to cope with physically supporting the instrument's weight when the solution would naturally be that a trombone needn't be supported only by hand in the first place! Neither saxophones, bassoons nor violoncellos are supported merely by static tensed hands or knees (violoncello). Even many clarinetists and oboists nowadays prefer to support the few hundred grams of their instruments with their body rather than with their hands only [22].

This trombone aid was subsequently adapted to suit the needs of trumpet players. The resultant *ERGObrass* supports the weight of the instrument on a rod attached to the floor or to the player’s belt, thereby freeing up the arms, shoulders, and upper body. In addition to improving the comfort of the player, it is also claimed to be beneficial to their performance [23].

As entirely passive devices, neither the Shulman System nor the *ERGObrass* harness any of the possibilities of the computer. However, a number of computer-based and computer-assisted posture aids can be found in other instrumental domains. The Music Jacket [13] is a computer-controlled wearable system intended for novice violin players. It consists of two elements. A commercial motion capture system is used to track the trajectory of the bow. Haptic feedback is then applied if the player does not hold their instrument correctly or adopts poor bowing technique.

The *Integrated Vibrotactiles* interface [24] is quite similar and also aimed at violin players. Like the Music Jacket, it provides the player with real-time haptic feedback in an attempt to foster good movement and posture in 3-D space. Elsewhere, Mora *et al.* [25] present a system aimed at piano players which is broadly comparable to the Music Jacket in that it uses a motion capture system to analyze posture. However, there is no haptic component; it offers three-dimensional visual feedback only. At a larger scale, Hadjakos *et al.* [26] have used the Kinect camera to perform motion analysis of small music ensembles. Mounted overhead, several feet above the floor, the Kinect was used to track the heads of musicians over the course of practice and performance. Indeed, the hackability of the Kinect is such that it has found numerous applications within the NIME community.

The notion of computer-assisted instrumental tuition is also relevant. However, in many cases the integration of technology into teaching has often centered on the desktop. For instance, in their discussion of the ‘practice room of the future’ Hochenbaum and Kapur [27] note that while most music programs incorporate technology, this typically involves the ‘keyboard lab’ model. While they consider the MIDI keyboard interface useful in some respects, they suggest that it is also a barrier to experiencing the physical realities of instrumental performance. This leads them to contend that the need for specialist advice around these areas preserves the role of the tutor. However, more technologically novel approaches have been developed. For example, at the 2013 NIME conference, Schacher [28] presented an educational program that uses DMIs to fuse instrumental practice and gestural interaction in situ.

3. THE POSTRUM PROTOTYPE

The *Postrum* system surveys the posture of the user then applies real-time haptic feedback to the body of the user. Guided by review of the literature of brass pedagogy, and the posture issues identified in Figure 1 in particular, the *Postrum* prototype was developed via a process of sketching in hardware and software over the course of several weeks. The system was informally tested from the outset of its development, with the discoveries made feeding into and informing subsequent iterations. A number of different technologies and configurations were tried. For instance, different types of camera were tried, from simple webcam to HD video camera and Microsoft Kinect 3-D camera. We also trialed the use of instrument-mounted sensors (e.g. accelerometers, gyroscopes and magnetometers) to supplement the camera input, but these were found to be unnecessary at best. Thus, as of summer 2014, the Postrum prototype (Figure 3) consists of three main elements:

1. 3-D camera-based sensing (input)
2. real-time directional haptic feedback (output)
3. a software mapping layer that spans and joins the two.

Figure 3: A trumpet player wearing the Postrum prototype.

4.1. Camera Input

A Microsoft Kinect for Xbox 360 sensor is used to survey the body of the user. This consists of a RGB camera capable of 30FPS, an infrared (IR) depth sensor that can operate at distances of 80-400cm, and a multi-array microphone. The microphone is not used here. The Kinect is placed to the side of the player and relies on a USB connection to a host computer, and Synapse [29] for image analysis. Data from some 15 major joints (neck, shoulders, elbows, wrists, etc.) are used to produce a real-time skeleton model. This model is then converted to Open Sound Control (OSC) format data and sent to a MaxMSP client.

4.2. Mapping

The Max client is calibrated to recognize the postures identified in Figure 1 and Figure 2, with the exception of the sideways twisting posture (far right in Figure 1); this cannot be reliably recognized with a single, side-on camera. To reduce the possibility of spurious responses to minor or occasional deviations from the optimal posture, a small null zone is implemented.

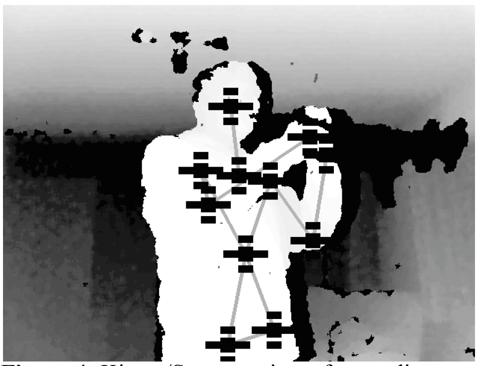

Figure 4: Kinect/Synapse view of a standing posture.

Figure 5: Kinect/Synapse view of a seated posture.

When one the posture of the player is identified as problematic, one or both of two torso-mounted vibrotactile arrays are activated. The haptic force exerted on the player is a repulsive one, and is also proportional to the amount of deviation from the optimal position. However, to avoid postures that are borderline or only very occasionally problematic producing spurious activations of the haptic feedback system, rapid changes of state are ignored: there must be a departure from the ideal posture for at least two seconds in order for the haptic system to be activated.

4.3. Haptic Feedback

Each array consists of four vibrotactile motors arranged in a 2x2 grid. These are mounted inside a small box and then placed inside a flexible belt to press them against the flanks of the player. One 4-channel H-bridge is used per array, mounted on an Arduino microcontroller. These connect to a host computer via standard USB cables. The Firmata protocol and Maxuino firmware are used to toggle the pins of the microcontrollers on and off from within Max. This rudimentary pulse-duration modulation (PDM) enables the amplitude of each motor to be controlled independently. Thus, in terms of the repulsion metaphor, if the head droops forward, the upper motors of both arrays start to pulse. If the head and body both droop forward, a pulse appears to move repeatedly from the lower motors of both arrays to the upper ones. The severity of the deviation from the ideal posture determines how smoothly or abruptly the pulses transition from one motor to the next.

4. Discussion and Future Work

Informal ‘hallway’ testing of this system has suggested that haptic feedback may not have the immediacy of other feedback modalities, and that it is perceived as ‘quiet’ or ‘subtle.’ This also tallies with earlier work by one of the authors and collaborators [30]. However, this relative subtlety may be advantageous in a music practice context. For instance, visual feedback may draw the eye of the user away from a score, thus making it more difficult to follow. Similarly, audio feedback may drown out the sound of the instrument (or itself be drowned out). Sound spill may also be problematic, particularly in group practice contexts. By contrast, haptic feedback has the potential to discreetly alert the user to incorrect posture without causing significant disruption to either solo or group practice.

Even at this early stage, it is interesting to consider the implications for the ‘practice room of the future.’ Unlike most of the computer-assisted systems mentioned by Hochenbaum and Kapur [27] and their own *Ezither* hyper-instrument, the *Postrum* prototype does not require any modification to be made to the instrument, and needs very little adjustment to the practice room. While the prototype system currently tethers the trumpet player to within a few feet of a laptop computer via a USB cable, a move over to a wireless connection between player and computer would solve this issue and enable the player to move more freely.

Based on our initial observations, the original vibrotactile motors have already been replaced with a larger and more powerful type. It is plausible that this will improve the immediacy (i.e. the perceived ‘punch’ or impact) of the haptic feedback system, and a design study will be carried out in an attempt to quantify the effectiveness of the directional haptic system. This may compare, for example, conventional (i.e. non-technologically aided) instrumental practice, instrumental practice that involves visual feedback, and instrumental practice where the player is provided with directional haptic feedback as per the Haptic Drum Kit [30].

Another limitation of the current system is the use of single camera. The addition of a second camera would enable players to be observed from the front and side simultaneously. Thus, a wider range of posture problems could be identified, for instance those related to bodily asymmetry. This shift may also have some additional advantages. For instance, it may make the recognition of current posture types more robust by reducing the possibility of occlusion, and enable two inexpensive generic (2-D) cameras to be used in place of the single (but significantly more expensive and narrowly compatible) Kinect peripheral.

In the longer term, overcoming the reluctance or ambivalence of potential users will be key to increasing adoption. Many people now own a smartphone or tablet, and often become very attached to these devices. The ability to run the *Postrum* system (or similar) on users' existing devices can therefore be seen as one way to encourage adoption. It is therefore hoped to eventually migrate to less-specialized hardware and cross-platform code.

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